METHOD FOR GROWTH OF INDIUM-CONTAINING NITRIDE FILMS

FIELD

The present disclosure relates generally to techniques for growing indium-containing nitride films. More specifically, the disclosure includes a process for forming materials such as InGaN and/or AlInGaN or AlInN that are nucleated heteroepitaxially directly on a substrate without first forming crystalline GaN. In various embodiments, deposition is performed at relatively low temperature, via molecular beam epitaxy, hydride vapor phase epitaxy, metalorganic chemical vapor deposition, or atomic layer epitaxy. There are other embodiments as well.

BACKGROUND

Indium-containing nitride films are important in a number of applications, including epitaxial InGaN layers in light-emitting diodes and laser diodes. Typically, these films are grown on a GaN layer, which in turn is either deposited heteroepitaxially on a non-GaN substrate such as sapphire or silicon carbide, or homoepitaxially on a bulk or quasi-bulk GaN substrate. Unfortunately, these conventional techniques are often inadequate. Thus, improved method and system for forming indium-containing nitride films are desirable.

BRIEF SUMMARY

The present disclosure relates generally to techniques for growing indium-containing nitride films. More specifically, the disclosure includes a process for forming materials such as InGaN and/or AlInGaN or AlInN that are nucleated heteroepitaxially directly on a substrate without first forming crystalline GaN. In various embodiments, deposition is performed at relatively low temperature, via molecular beam epitaxy, hydride vapor phase epitaxy, metalorganic chemical vapor deposition, or atomic layer epitaxy. There are other embodiments as well.

According to one embodiment, the disclosure provides a method for fabricating a gallium, indium, and nitrogen containing material. The method includes providing a substrate having a surface region. The method also includes forming a first thickness of material having a first indium-rich concentration. The method includes forming a second thickness of material having a first indium-poor concentration overlying the first thickness of material. The method additionally includes forming a third thickness of material having a second indium-rich concentration to form a sandwiched structure including at least the first thickness of material, the second thickness of material, and third thickness of material. Moreover, the method includes processing the sandwiched structure using at least a thermal process to cause formation of well-crystallized, relaxed material within a vicinity of a surface region of the sandwiched structure. The sandwiched structure has an overall thickness of 100 nm and greater.

According to another embodiment, the present disclosure provides an indium, gallium and nitrogen containing substrate structure. The structure includes a substrate comprising a surface region. The structure also includes a thickness of a gallium, indium, and nitrogen containing crystalline material overlying the surface region and configured in a stain free manner from an alternating sequence of at least two materials including an indium and nitrogen containing material and a

gallium and nitrogen containing material. The thickness is at least 100 nm and is substantially strain-free and well-crystallized.

Among the benefits of the disclosed techniques are InGaN and/or AlInGaN or AlInN are nucleated heteroepitaxially directly on a substrate without first forming crystalline GaN. Deposition is performed at relatively low temperature, via molecular beam epitaxy, hydride vapor phase epitaxy, metalorganic chemical vapor deposition, or atomic layer epitaxy, in order to avoid undesired segregation and facet formation. The crystalline InGaN or AlInGaN or AlInN film formed thereupon has superior homogeneity at thicknesses greater than about 500 nm than the prior art. In a specific embodiment, the techniques according to the present disclosure can be performed in a relatively simple and cost effective manner. Depending upon the embodiment, the methods and systems according to the present disclosure can be performed using conventional materials and/or equipments according to one of ordinary skill in the art. There are other benefits as well.

A further understanding of the nature and advantages of the techniques of the disclosure may be realized by reference to the following specification and attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is simplified diagram illustrating a substrate for processing according to an embodiment of the present disclosure.

FIG. **2** is a simplified diagram illustrating using a reactor **200** for processing one or more substrates according to an embodiment of the present disclosure.

FIG. **3** shows a cross-sectional view of a reactor near the susceptor according to an embodiment of the present disclosure.

FIG. **4** is a simplified diagram illustrating using a reactor **400** for processing one or more substrates according to an embodiment of the present disclosure.

FIG. **5** illustrates a suitable sequence of gas flows to enable deposition of alternating indium-rich and indium-poor layers according to an embodiment of the present disclosure.

FIG. **6** illustrates a showerhead system for processing a substrate according to an embodiment of the present disclosure.

FIG. **7** is a simplified diagram illustrating a gas flow system for processing a substrate according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

The present disclosure relates generally to techniques for growing indium-containing nitride films. More specifically, the disclosure includes a process for forming materials such as InGaN and/or AlInGaN or AlInN that are nucleated heteroepitaxially directly on a substrate without first forming crystalline GaN. In various embodiments, deposition is performed at relatively low temperature, via molecular beam epitaxy, hydride vapor phase epitaxy, metalorganic chemical vapor deposition, or atomic layer epitaxy. There are other embodiments as well.

As explained above, conventional techniques for forming crystalline GaN and indium-containing nitride films are often inadequate and have various limitations. It is well known that as the fraction of InN in the InGaN layer increases beyond a certain point, the internal quantum efficiency for light emission decreases severely—a phenomenon known widely as the "green gap." The lattice constant of InN is significantly larger than that of GaN and, for higher In fractions in an InGaN